Chapter 5

Piagetian Structures and Psychological Constructivism

Toward the end of the first decade of the twentieth century, Jean Piaget (1896–1980), a Swiss, was offered a full-time post as scientific curator of a museum collection of mollusks, on the basis of some papers he had published on the subject. He declined, on the grounds of age—he was still a secondary-school student! Thus began the career of the world's most eminent developmental psychologist, a man whose work has exerted extraordinary influence on contemporary views of the nature of learning.

His early biological training—he took his doctorate at the age of twenty-one for work on the evolution of the shellfish of Valais—indelibly stamped Piaget's approach to human learning. Like Dewey, he believed that the human capacity to think and to learn was an adaptive feature: its biological function was to aid the individual in dealing fruitfully with the surrounding environment. And, like Köhler, he carefully studied a small number of learners, setting ingenious little problems for them to solve, and making careful observations of their attempts. However, he did not study chimpanzees; he worked with young humans, particularly his own three children whom he studied intensively from the moment of their births. Furthermore, as a trained biologist he was comfortable with the notion that, in living organisms, important functions are carried out by biological structures. (Thus, the function of respiration is carried out by structures known as lungs or gills, the function of circulation of blood is carried out by a muscular structure, the heart, and so on.)

It is no surprise, then, that Piaget approached the function of thinking and learning in terms of the mental or cognitive structures that make it possible. Piaget seems to have regarded these structures as being quite real, although they are unobservable. It is quite scientific to study unobservables, providing one is careful about evidence and providing that any theories that are produced are testable by other scientists. (Recall that physicists often postulate unobservables.)

The Development of Cognitive Structures

Piaget was above all a developmentalist. He clearly recognized that children come into the world with minimal equipment to guide their behavior—merely a few inborn reflexes such as sucking and crying. Yet within a few years they are able to walk and talk, and deal with common everyday objects and situations. Within a few more years they become proficient problem solvers, and somewhere in their teens they are able to deal with quite abstract matters. What is happening during these formative years when children are learning so much?

In essence, Piaget believed that the developing child was busy constructing cognitive structures. At first the child had to learn to coordinate its physical movements—grasping, bringing objects to its mouth, and so on. Piaget spoke of the child constructing a schema for each of these complex activities; in terms of our well-worn computer and robot analogy, a schema is rather like a computer program. Thus, a mobile, computerized robot will have in its data banks various programs, or sets of directions, for moving its mechanical arm in various ways depending on the different situations it might encounter. The only difference, and of course it is a highly significant one, is that the Piagetian child constructs the programs personally (like learning to eat with a spoon), while present-day robots are given them. At any rate, at first the child is busy about this business, and Piaget distinguished this as his first developmental stage—the sensorimotor stage, lasting from birth to about the age of two. (A "developmental stage," of course, is another conception Piaget took over from biology; it is a commonplace that mollusks, insects, and so on pass through various stages during their life cycles.)

Like the learner depicted by Dewey, and even like Köhler's Sultan, the Piagetian child was described as very actively exploring its environment. As a result of handling, dismantling, and generally transforming its surroundings, the child gradually derived a set of concepts that were fruitful; at the same time the child started to "interiorize" its actions, that is, it started to build up a scheme or program of the actions it was performing upon its environment. Piaget called these latter conceptualizations "operations."

Now, the operations and other concepts being formed did not rest as a disconnected "lump" in the child's mind; they were interrelated or organized, and thus they formed a network, a cognitive structure. During the second developmental stage—the preoperational stage, from about ages two to seven—the child was still not able to conceptualize matters in the abstract, that is, to operate on them solely with the mind. The child had to have the concrete physical situation in front of it.

It will be recalled that in programming a computer, nothing can be taken for granted. Absolutely everything that the computer needs to have, either in its operating programs or in its data bank, has to be put there—the computer scientist needs to pay painstaking attention to detail. Similarly, if the computer was self-programming, everything it ended up "knowing" or being able to do would have had to be constructed from scratch. Now, there are many important things—things that are vital for dealing with the environment—that human adults take for granted, and most people do not realize must have been learned. Such things, for example, as the fact that physical objects have a permanent existence and do not cease to exist when they are out of sight, or, to take another example, the fact that the volume of a liquid does not alter when it is poured from one container into another of a different shape. Young children, Piaget discovered in a series of wonderfully striking experiments, do not know these things. Although "object permanence" is discovered quite early by the baby in its crib, conservation of volume, and the reversability of some operations (quantities that can be added together can be subtracted apart), and so on, are discovered relatively late. One of Piaget's most convincing demonstrations is worth describing: He took two identical balls of clay, and asked a child if one was bigger than the other. "No." Piaget then rolled one of the balls into a sausage shape and repeated the question. This time the child said the sausage was bigger. He then rolled it back into a ball shape, to be told it now had the same amount of clay as the other ball. Piaget found that only quite old children conserved volume and held that the sausage and the ball were still the same.

It is only during the third developmental stage—the concrete operation's stage, from about seven to eleven—that the child finally starts to conceptualize these things, and only after a great deal of actual physical experience with objects has accumulated. Piaget speaks of "logical structures" being constructed. At this stage, addition, subtraction, multiplication, and division can be done with numbers and not just with things.

Finally, its structures become close to those of the adult, and the young learner is able to solve problems in the abstract; conceptual reasoning has been mastered. This is the fourth stage, formal operations, from around the age of eleven to about fourteen or fifteen.

By way of summary, consider Piaget's words:

> Actually, in order to know objects, the subject must act upon them, and therefore transform them: he must displace, correct, combine, take apart, and reassemble them. From the most elementary sensorimotor actions (such as pushing and pulling) to the most sophisticated intellectual operations, which are interiorized actions, carried out mentally (e.g., joining together, putting in order, putting into one-to-one correspondence), knowledge is constantly linked with actions or operations, that is, with *transformations*.[1]

Although this theory looks complex, there is a great deal of sense and order to it. Imagine our computerized robot again. If it were turned loose with only a minimal amount of direction, it would first have to "learn" to move effectively, and this would require it to produce a series of programs (action schemata). Then it would have to build up some information in its data banks about its surroundings—what the features were of the things it was bumping into, for example. Then, and only after it had acquired considerable experience, would it be able to formulate principles about how these things behave and what their properties were (object permanence, conservation of volume, and so forth). Finally, it would then be in a position to be able to predict beforehand (that is, "mentally") what might happen if it were to act in certain ways. The "logic" of this progression of stages seems fairly compelling—the robot could not make successful predictions about the behavior of things in its environment until after it had acquired an "understanding" of the properties of these things by operating on them, and in turn this would require that the robot have a stock of concepts in terms of which it could "think" about its environment.

So, then, there is a lot to be said for Piaget's view of the order in which knowledge is built up (although it should be noted in passing that criticisms of Piaget's work are mounting). But can anything more concrete be said about how structures are constructed?

The Principles of Construction

Biologists know that, in many instances, when one of the human body's delicately adjusted systems is thrown out of balance, say by some outside environmental influence, the affected system will respond so as to restore equilibrium. The human body has many feedback mechanisms that help to monitor and maintain constancy in this way. Consider body temperature: a rise of only a few degrees can have serious ill effects, and an increase of a few more can result in death. So, when faced with such a threat—let us suppose that the body is hot from extreme exertion—the body's systems respond by producing sweat, the evaporation of which is cooling, and also more blood is sent through the vessels near the skin in an effort to allow heat to escape. In this way the body accommodates to the presence of heat, and equilibrium is restored.

Piaget used a similar approach to explain how cognitive structures develop—he borrowed the biological notions of assimilation, accommodation, and equilibration. At any stage of his or her development, the young learner will be interacting with the environment, using whatever cognitive structures have been constructed up to that moment. If the experience is one that has been engaged in many times before, for example, being generally successful in judging the quantity of water in a glass using height as the key, the learner will be able to deal with it satisfactorily. The experience will be assimilated in terms of the present structures, and mental equilibrium will be preserved. Most likely, however, because the learner is still learning, his or her structures will not be able to completely handle some new experience (Piaget's ball and sausage of clay, or the tall-thin and short-wide containers of water). At some point there will be a loss of equilibrium, and some change (most likely an addition) will be made to a cognitive structure in an attempt to accommodate to the novel aspects of the experience. Thus the learner might acquire a new concept, or a new principle such as the principle of conservation of volume. In this way, little by little, in a cycle of attempted assimilation leading to accommodatory change and returning to equilibrium, more and more adequate cognitive structures will be built up:

> Intelligence, whose logical operations constitute a mobile and at the same time permanent equilibrium between the universe and thought, is an extension and a perfection of all adaptive processes. . . . Only intelligence, capable of all its detours and reversals by action and by thought, tends towards an all-embracing equilibrium by aiming at the assimilation of the whole of reality.[2]

Once again our trusty analogy is useful. Imagine our computerized robot let loose in a room that it has not yet completely conceptualized—it is still in the process of perfecting its programs and data banks. Suppose, then, that the robot detects an object in front of it, and changes direction in order to avoid collision. So far, so good—the situation seems to have been assimilated to the robot's present knowledge. But suddenly, disaster! The robot hits the object it had attempted to avoid. Its internal equilibrium is upset, for the new direction was supposed to have prevented a collision. Accommodation of its data bank is called for, or perhaps of one of its programs. It might not, for example, have changed its direction of motion properly. So some change will be made (maybe its conception of the shape of the object is adjusted), equilibrium is restored, and the robot proceeds on its way until the next intellectual crisis. To an outside observer it may well look like a case of common trial-and-error learning.

We can imagine that in the long run, provided that the room is not altered, the robot will build up a perfect internal structure that never gets thrown out of equilibrium. The robot would then have intellectually mastered the problems associated with its movement around the room.

While this piece of science fiction helps to make Piaget's theory understandable on one level, it also serves to highlight a number of problems—problems the pursuit of which will push our understanding of learning still further along, until we reach equilibrium.

Case One

Before dealing with the critique, let us consider a case that seems to have some of Piaget's principles of learning embedded in it. As you read it, ask yourself to what extent Piaget's theory provides an adequate explanation. Can any of the other theories treated thus far be used to throw light on what was learned at Staple High?

> Harry Strong, the math teacher and football coach at Staple High, took pride in both of his roles as a teacher. He not only taught basic skills in both areas, but helped students develop strategies for solving problems and dealing with difficulties. Team members and the math students liked Mr. Strong. He didn't yell at them when things went wrong; instead, he'd get them to think about what they were doing and how they might alter their strategies. Here are a couple of examples:
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> At halftime last week, the team was losing to Central High. In previous years, when they had played Central, their opponents had run the ball mercilessly and Staple worked hard to contain this running attack. But this year Central took to the pass and caught Staple by surprise, quickly scoring three touchdowns. The defense was totally confused. In the locker room at halftime, Harry Strong asked for an analysis, and the team agreed that they were poised primarily to stop the run. Now, however, it seemed they needed to change their strategy and to anticipate more passing. Mr. Strong made some changes in the defensive secondary, with the result that Central's passing did not hurt them as much in the second half. Even though they lost the game, they were able to come within three points and were proud of their effort. They had learned something in the process, too.
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> One day last week Juan Valdez, Mr. Strong's best math student in geometry, brought in a problem he couldn't solve. Mr. Strong asked him how he was approaching the problem. Juan replied that he first tried to think of the axioms, postulates, and theorems that seemed relevant to a problem, then he would write them down and move them around into what intuitively seemed promising proof patterns. He showed Mr. Strong pages and pages of notes and scribbles trying different patterns, but none seemed to work for this particular problem. Juan felt that he had exhausted all the possibilities. "Why not try another approach," Mr. Strong counseled.
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> "Ever try a visual/figure drawing in the search for possible solutions?" he asked.
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> Juan hadn't, but it didn't take him long to follow this new lead. Mr. Strong put him to work at the blackboard, raised some helpful questions at the same time, and very quickly Juan found a solution to his problem and learned a new way to deal with geometric problems.

Some Critical Issues

In the first place, there are several mysteries concerning the mechanisms that, according to Piaget, lie behind the construction of structures. What does it mean to say that a cognitive structure has been put out of equilibrium? It is clear that a physical structure—say, a model made of building blocks, or a house of cards—can lose equilibrium, but a cognitive structure is not physical. It cannot topple over. This is just a misleading figure of speech. So, when Piaget asserts that a learner's cognitive structure changes because it is out of equilibrium, is he saying anything more than that it is changing? And if so, then he has not explained why change occurs. (It might be thought that Piaget could respond that the cognitive structure changes because it does not match up with reality, but this response would be like leaping out of the frying pan and into the fire. Who makes the judgment that the structure does not match? Are we implying that there is a little judge, an "homunculus," resting in the mind, that can see both reality and the cognitive structures and can compare them? Furthermore, Piaget—along with many other philosophers—seems to agree that each of us only sees "reality" through the medium of our cognitive structures, and so we cannot escape outside of these structures to see if they do correspond with reality!)

Similar problems beset the notion of accommodation. Hasn't Piaget again begged the question? When asked how it is we can learn a new concept, he replies it is because we make an accommodatory change. But what is an accommodation? Why, it is merely the adding of a new concept! He certainly has *named* the process, but has he explained it?

This leads to some other serious matters. Even if they were not subject to the criticisms above, the mechanisms postulated by Piaget are not powerful enough to account for the phenomena. For Piaget has insisted that *all children,* everywhere in the world, go through the same developmental sequence (although he also said that the ages at which children enter and leave the various stages will vary according to the society and the environment in which they are located). Now, when *all* members of a species pass through the same stages, the mechanism involved is a powerful one; in insects, for example, the stages of the life cycle are determined by genetic factors—that is why *all* insects pass from egg to larva to pupa to adult. But Piaget resisted saying the same thing about cognitive structures; they develop because of equilibration and the rest. Can such a mechanism be adequate?

To highlight the issue here, imagine several different robots let loose in a room. Is it at all certain that they would conceptualize it in identical ways? What if the room were very complex, and the objects in it behaved in intricate ways? It is not clear that all conceptualizations would be the same. Other researchers have felt the force of this problem, and some have decided that at least the basic parts of cognitive structures must be predetermined by genetics. Linguist Noam Chomsky argues this way—the "deep structures" that govern acquisition of language by all humans are predetermined. Still others have held that social forces are at work steering the child's early attempts at learning (for example, parents, teachers, language, customs, the media), and this is why children develop along very similar paths. (All human societies, despite marked "surface" differences, work on basically similar lines, they argue. The Russians Luria and Vygotsky were prominent supporters of this general approach to human development, as we will see in more detail shortly.) A common criticism of Piaget has been that he underemphasized the importance of the social environment; he did mention it, but generally it received little attention in most of his books.

If Piaget has not given a convincing account of how knowledge develops, then he might not have escaped the force of Plato's problem. How *could* a computer, with nothing in it, develop something? How can a child, with no cognitive structures, start to develop them? There would be nothing there, at first, that could lose its equilibrium; there would be nothing there, at first, with which the world could be assimilated; and there would be nothing there, at first, that would require accommodations to be made. So, if there was nothing there, how could anything ever get there by the mechanisms that Piaget formulated?

Finally, there have been challenges made to some of the striking data that Piaget collected. His interviews with children, which yielded such interesting things as the "balls of clay" demonstration, were clinical interviews. They were often somewhat open-ended, and Piaget felt free to vary the procedure he was adopting in an interview, depending upon individual circumstances. Recently, researchers have suggested that other explanations are possible for the phenomena Piaget uncovered in this way; if very carefully controlled and standardized procedures are adopted, they claim, the phenomena turn out differently.[3]

Guidelines for Educators

In the long run, it might not matter much if the details of Piaget's theory collapse under criticism. His work will still stand as a turning point—he showed the way to a new approach to understanding the developing

learner. He has alerted us to a number of important things, whether or not he got the details wrong!

First, after Piaget, what educator who takes teaching seriously will ignore the fact that students may be developing through stages? Even more significantly, at some stages the students might not yet have developed the logical or conceptual equipment to be able to tackle certain types of problem—which is a different problem from their not having had the experience. The alert educator, then, will be concerned to select material that is appropriate to the developmental stage of the learner.

Second, after Piaget, who could ignore the role played by experience in education? A learner who has not encountered certain types of experience may also, and as a result, lack certain fundamental concepts. The learner might know the word, but this is not the same as having mastered the concept. (Every male parent has been embarrassed by the evidence that his offspring has learned the word "Daddy" but has not mastered the concept thus, all men encountered, usually in the supermarket, are greeted with this title!)

Third, after Piaget, we should all be alert to the role played in learning not only by concepts but by principles such as conservation of volume, reversibility of logical operations, and object permanence as well as other mental categories treated by Piaget such as cause, time, space, and number.

Finally, after Piaget, only the insensitive teacher would be unaware that, in the course of learning, the student is not merely amassing concepts and operations and schema, but is *organizing* them internally in some way. Compare the ease of using a library that is logically laid out with one where the volumes have been thrown together haphazardly. A successful learner can readily retrieve what he or she has learned—a matter that will be pursued in the following discussion. Before continuing, you may want to give some thought to "Teaching, Learning, and Stages of Development" in Chapter 10.

Constructivist Approaches to Learning After Piaget

Piaget's theory about how young learners construct their knowledge structures has been one of the inspirations behind at least some of the work done by members of the contemporary movement known as *constructivism* in education. Considered as a whole, this movement is very complex, and is made up of a number of (sometimes warring and quite incompatible) sects. One group, the so-called social constructivists, is concerned with how the public bodies of knowledge—the disciplines that form much of the content of the school curriculum that students strug-

gle to learn, such as science, math, history, economics and so on—have been constructed by communities of inquirers over long periods of time. These scholars oppose the view that knowledge is built up by isolated individuals, and they stress that knowledge construction within the disciplines is a social activity. (For an outline of this view, and a picture of the whole confusing constructivist scene, see Phillips, 1995, in the "Notes and References" section. We shall also touch on this social form of constructivism in a later chapter.)

For our purposes in the present chapter, however, it is the *psychological constructivists* whose work is most relevant. These researchers focus upon how learning occurs in individuals and on how internal cognitive or memory or knowledge structures are built up or constructed. Some if not all of the figures we shall discuss in the next two chapters can be regarded as constructivists in this sense. But a particularly influential line of work that has been greatly inspired by Piaget is being carried out in the fields of science and mathematics education. One of the psychological constructivists working here, Ernst von Glasersfeld, is quite eclectic and seems to have been influenced by empiricist philosophers such as John Locke in addition to Piaget and the Continental philosopher Immanuel Kant. Von Glasersfeld refers to himself as a "radical constructivist."

In brief, von Glasersfeld argues that the individual learner is *not* the recipient of knowledge that is pressed onto his or her consciousness by some "external reality." In this regard he differs markedly from Locke and also from Plato. But, similarly to Locke, he seems to hold the view that each individual is only in "contact" with the impressions (or stimuli or experiences) that are received via the sense organs. Thus the task for the learner is to construct a body of knowledge on the basis of these sense impressions, knowledge that will help the individual to adapt to the environment in which he or she is situated. One of the controversial "twists" that von Glasersfeld gives to this basic story is that he asserts that we have no grounds for believing in any form of "external reality"—each one of us seems to subjectively construct a functionally adequate set of beliefs, but these cannot be held to "objectively represent" whatever reality exists external to our cognitive apparatus! (Here von Glasersfeld seems indebted to Kant, who referred to this "external realm" as the realm of "things in themselves" or "noumena"—which are unknowable.)

Nor can we suppose, according to von Glasersfeld, that other individuals construct structures that in any way resemble our own; teachers cannot assume that the "understandings" of their students resemble their own. It might even follow, from this position, that each of us has no solid grounds for believing that other individuals exist—after all, *you* might merely be a "construction" that my mind has made![4] On the other hand,

Piaget believed that the knowledge constructed by all individuals has the same structural features, and the reason we make the same or similar constructions is because we are dealing with the same reality.

Some of these complexities emerge in the following passage written by von Glasersfeld as part of the introduction to a collection of essays:

> The notion that knowledge is the result of a learner's activity rather than that of the passive reception of information or instruction, goes back to Socrates and is today embraced by all who call themselves "constructivists." However, the authors whose work is collected here, constitute the radical wing of the constructivist front.... This attitude is characterized by the deliberate redefinition of the concept of knowledge as an adaptive function. In simple words, this means that the results of our cognitive efforts have the purpose of helping us cope in the world of experience, rather than the traditional goal of furnishing an objective representation of a world as it might "exist" apart from us and our experience.[5]

What would a constructivist teacher be like? This is not a simple question to answer definitively, and in the literature there are hundreds of references to this topic. Furthermore, as von Glasersfeld stresses, radical constructivism does not entail that there is only one right way to teach, so it cannot

> produce a fixed teaching procedure.... As I have often said, constructivism cannot tell teachers new things to do, but it may suggest why certain attitudes and procedures are fruitless or counter-productive....[6]

This point is well taken, but nevertheless we think there are strong grounds for claiming that a good constructivist teacher will be indistinguishable from a good progressive educator who works according to the principles put forward by John Dewey. Students will be actively engaged with interesting and relevant problems; they will be able to discuss with each other and with the teacher; they will be active inquirers rather than passive; they will have adequate time to reflect; they will have opportunities to test or evaluate the knowledge that they have constructed; and they will reflect seriously about the constructions produced by other students and by the teacher.[7]

It is easy to see the similarities between Piaget and the radical constructivists. Among other things, they share a common concern with what is happening in the adaptive cognitive apparatus of each individual learner. As we shall see in the next chapter, however, there are strong intellectual currents in the contemporary world that move us in a more *social* direction.